# Enhancing Profitability And Reducing Environmental Impact

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## Introduction

We must have food production systems that are sustainable over time. These systems must be competitive and more productive than existing management schemes. The dairy industry has some inherent advantages compared to other animal industries when it comes to implementing truly sustainable cropping and feeding systems. These systems will revolve around high yielding crops (biomass) that produce nutrients in proportion to animal need, and likewise which proportionately utilize the nutrients in dairy manure. It is likely that high moisture feedstuffs, such as ensiled forages, high moisture grain and crop by-products, will continue to increase in dairy diets. Dairy manure is also high in water content, so the distance that high moisture feed and manure can be economically transported is limited. Crop production will need to be more closely situated to the dairy enterprise, and management of nutrients, particularly nitrogen and phosphorus, will require care to avoid serious nutrient accumulation and consequent contamination of ground and surface waters.

Content

***"Corn silage and alfalfa hay or silage are the two most important forages in US dairy diets."***

***"Feeding a blend of low protein corn silage with the high but easily degraded alfalfa protein enabled more efficient utilization of protein in the rumen."***

## Forage Source – Corn Silage or Alfalfa Silage?

Corn silage and alfalfa hay or silage are the two most important forages in US dairy diets. They are complimentary feedstuffs in that alfalfa is high in protein and corn silage is low. They are complimentary crops in that the nitrogen fixing legume is an ideal crop in rotation with corn. Corn silage will yield substantially more biomass per acre and typically at lower cost per ton of dry matter than alfalfa. On the other hand, producing corn silage presents greater environmental risk, even more than growing corn for grain, because virtually no crop residue remains following harvest. Identifying the optimum blend of these two forages for a given dairy operation (where both forages can be produced) is truly a systems question, taking into account soil quality, nutrient management, labor supply, feed storage, cow response, etc. We wanted to know, from the cow's point of view, what the optimum mix of these two forage sources would be in a dairy ration where the grain mix was largely corn and a soy based protein source. The experiment started at calving, and lasted until cows completed 44 weeks of lactation. Forty-five mature cows and 29 first lactation cows were randomly assigned before calving to one of three treatments according to calving date. In our experiment cows were fed diets containing 50% forage and 50% concentrate. The forage portion of the diet was either all alfalfa silage (AS), 2/3 alfalfa silage and 1/3 corn silage (2/3 AS), or 1/3 alfalfa silage and 2/3 corn silage (1/3 AS).

The ingredient and chemical composition of diets are given in Table 1. Diets, 1, 2 and 3 were fed until cows were 12 weeks in lactation. After 12 weeks, cows were switched to diets 4, 5 and 6 unless milk yield was above 85 lb/day for mature and 65 lb/day for first lactation cows. Alfalfa silage and corn silage had 20 and 8% crude protein, respectively. Diets were fed as a total mixed ration once daily.

Milk production totals, unadjusted for milk fat content, for mature cows for the 305 day lactation for the AS, 2/3 AS and 1/3 AS treatments were 21,148, 22,422 and 22,100 lb; and for first lactation cows were 17,911, 18,546 and 18,008 lb. From the point of view of animal performance only, the 2/3 alfalfa silage-1/3 corn silage diet was optimal. The important point is that while there appears to be an optimum blend of the two forages, the difference in milk production is modest when comparing different proportions of the two forages. This is fortunate, for it gives the manager greater latitude in managing nutrients through both the cropping and feeding phases with these diverse feedstuffs.

As noted in Table 1, less total protein was fed when the diets contained corn silage, but more supplemental protein was required. Feeding a blend of low protein corn silage with the high but easily degraded alfalfa protein enabled more efficient utilization of protein in the rumen. This resulted in less nitrogen excretion per unit of milk produced when the forage mixture was used.

The whole system, both cropping and feeding, must be considered in the overall optimization of nitrogen dynamics on a dairy farm. It appears, however, that a blend of the two forages in dairy diets is advantageous for several reasons, including crop rotation considerations, nutrient management, labor distribution in crop management, and cow performance.

Table 1.
Ingredient and chemical composition of corn silage/alfalfa silage diets (% DM).

| | Diet | | | | | |
|---|---|---|---|---|---|---|
| Ingredient | 1 | 2 | 3 | 4 | 5 | 6 |
| Alfalfa silage | 50.0 | 33.0 | 17.0 | 50.0 | 33.0 | 17.0 |
| Corn silage | 0 | 17.0 | 33.0 | 0 | 17.0 | 33.0 |
| High moisture ear corn | 33.2 | 32.2 | 30.2 | 40.6 | 38.6 | 34.5 |
| Soybean meal 0 | 5.0 | 10.0 | 0 | 7.5 | 10.0 | |
| Roasted soybean | 9.0 | 5.5 | 2.5 | 3.0 | 0 | 0 |
| Meat and bone meal | 4.0 | 4.0 | 4.0 | 4.0 | 2.0 | 3.0 |
| Fat (hydrolyzed animal fat) | 2.1 | 1.4 | .8 | .7 | 0 | 0 |
| Bicarbonate 0 | .25 | .5 | 0 | .25 | .5 | |
| Premix of Ca, P, Mg, and S | 1.0 | 1.0 | 1.3 | 1.0 | 1.0 | 1.3 |
| Trace-mineralized salt | .7 | .7 | .7 | .7 | .7 | .7 |
| $NE_L$, Mcal/lb DM | .768 | .768 | .768 | .736 | .741 | .755 |
| Crude protein 18.6 | 17.5 | 16.6 | 17.0 | 16.1 | 15.5 | |
| Undegraded protein | 6.7 | 6.7 | 6.8 | 5.9 | 5.8 | 6.2 |

## Protein – The Most Limiting Nutrient in Alfalfa

The protein in alfalfa is very easily degraded by microbes in the rumen. The

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amount of ruminally undegraded protein ranges between 15-30% of total protein, with high moisture alfalfa silage (< 35% DM) at the lower end of this range and hay or relatively dry alfalfa silage (> 50% DM) at the higher end.

Conventional wisdom suggests that forages are limited in energy content, and that high forage diets are supplemented with grain to increase energy density of the diet. We designed an experiment to challenge this view (Dhiman and Satter 1993). High forage diets (75% alfalfa silage-25% supplement) were supplemented with fish meal and blood meal (high by-pass protein sources), fat (calories), and protein + fat or protein + glucose. The diets and the results are in Table 2.

Supplementation of protein, in contrast to supplementation of fat, increased milk and milk protein production. Supplementation of fat alone had little effect on milk production. Supplementation of both protein and calories resulted in milk yields similar to supplementation of protein alone. We have completed other studies where cows fed high alfalfa silage diets responded with a substantial increase in milk production to feeding of rumen undegraded protein (Cadorniga and Satter 1993), or to infusion of protein directly into the abomasum, but not to glucose infusion into the abomasum (Dhiman et al. 1993).

This series of experiments clearly indicated that, despite the high protein content of alfalfa, dairy diets containing large amounts of alfalfa protein were first limiting in protein, and secondarily limiting in energy. It is likely that one reason milk production is usually increased with addition of grain to high alfalfa diets is that microbial growth in the rumen is stimulated with the readily fermented energy. This results in trapping of more degraded alfalfa protein in microbial protein, thus improving the protein status of the cow. Using this line of reasoning, one can almost consider corn grain to be the cheapest protein supplement available when high alfalfa diets are fed.

Table 2.
Ingredient composition of diets and milk production of cows supplemented with protein or energy.

| | Diet | | | | |
|---|---|---|---|---|---|
| Item | Control | Protein | Fat | Protein + fat | Protein + glucose |
| | - - - - - - - - | - - - - - - - - | (% of DM) | - - - - - - - - | - - - - - - - - |
| Alfalfa silage | 75.0 | 75.0 | 75.0 | 75.0 | 75.0 |
| High moisture ear corn | 23.2 | 15.1 | 18.2 | 9.7 | 9.7 |
| Roasted soybeans | - - | - - | - - | - - | - - |
| Fish meal[1] | - - | 6.0 | - - | 6.0 | 6.0 |
| Blood meal | - - | 2.1 | - - | 2.5 | 2.5 |
| Fat[2] | - - | - - | 5.0 | 5.0 | - - |
| Glucose (infused) | - - | - - | - - | - - | 5.0[3] |
| Mineral vitamin mix | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 |
| $NE_L$, Mcal/lb of DM | .645 | .636 | .736 | .723 | .623[4] |
| CP, % of DM | 18.7 | 23.8 | 18.2 | 23.6 | 23.6 |
| RUP,[5] % of CP | 26.6 | 37.7 | 25.9 | 38.1 | 38.1 |
| Milk, lb/day | 65.1[c] | 78.5[a] | 68.2[bc] | 73.7[ab] | 77.9[a] |
| Milk protein, lb/day | 1.89[b] | 2.29[a] | 1.94[b] | 2.18[a] | 2.20[a] |
| Milk protein, % | 2.92 | 2.93 | 2.85 | 2.95 | 2.86 |
| Milk fat, % | 3.37[a] | 3.24[a] | 3.44[a] | 3.36[a] | 2.78[b] |

[1]SEA-LAC® ruminant-grade menhaden fish meal (Zapatan Hayne Corp., Hammond, LA).
[2]Energy booster® (hydrolyzed animal fat containing 38.7% palmitic acid, 41.8% stearic acid, and 12.6% oleic and linoleic acid; Milk Specialties Co., Dundee, IL).
[3]Dry matter attributed to glucose infusion for diet formulation purposes.
[4]Does not include the energy cows received from glucose infusion (1.6 kg/d of glucose per cow into the abomasum).
[5]Rumen-undegraded protein in roasted soybeans, fish meal, and blood meal was determined using an inhibitor in vitro method (1). For alfalfa silage and high moisture ear corn, NRC (16) means were used.
[abc]Means in the same row with different superscripts differ ($P < .01$).

## How Can Protein Utilization by the Cow be Improved When Alfalfa Containing Diets are Fed?

Basically three approaches are available for improving protein utilization with alfalfa containing diets: (1) decrease the degradability of protein in alfalfa; (2) decrease the degradability of protein supplements so the surplus of ammonia in the rumen from degradation of alfalfa protein is not exacerbated by excessive degradation of supplemental protein; and (3) stimulate the rumen fermentation, thus increasing microbial growth and conversion of degraded alfalfa protein into microbial protein.

Other programs at the US Dairy Forage Research Center are dealing with the first approach noted above. We have utilized the second and third approaches, focusing on the heat treatment of soybeans to increase the amount of rumen undegraded protein, and increasing fermentability of the diet by fine grinding of corn and roller milling of corn silage.

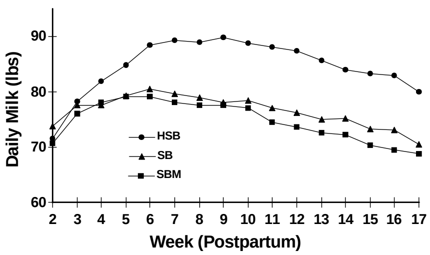


*Figure 1. Unadjusted mean daily milk production of cows supplemented with soybean meal (■) or soybeans (▲) or heat-treated soybeans(●).*

***"... there is little doubt that heated soybeans can be a very effective supplement, particularly when alfalfa silage or hay are the principal forages."***

## Decreasing Degradability of Protein Supplements. Heated Soybeans

Soy protein is by far the most common protein supplement for dairy cattle in the US; however, the protein in soybean meal is quite easily degraded. Only 30-35% of soybean meal protein escapes degradation, somewhat less than the 50% or more escapes degradation for meat and bone meal, blood meal, distillers and brewers grains, and fish meal. Full fat soybeans, while containing less protein (37%) than soybean meal (44%), do contain about 18% oil. Most high producing dairy herds are fed some fat or oil in the form of oilseed, tallow, or vegetable oil. Thus, full-fat soybeans are capable of providing both protein and oil to the dairy cow.

The protein in untreated soybeans is easily degraded, and only about 25% escapes degradation. With proper heat treatment, the amount of soybean protein escaping degradation can be doubled. We embarked on a program to identify the optimal conditions for heat treatment of soybeans. This involved a series of experiments where soybeans heated to various extents were measured for protein degradability and for lysine availability as indicated by both chemical tests and rat growth studies (Faldet et al. 1991; Faldet et al. 1992; Faldet et al. 1992). Lysine availability is a good indicator of heat damage to protein. From these studies it was concluded that soybeans must be heated to 295 °F ± 5 °, and then held (steeped) for 30 minutes prior to cooling. With this heat exposure, rumen undegraded protein is increased from 25 to 50% or more of total protein. We also standardized the Protein Dispersibility Index (PDI) test, long used in the soybean meal industry as an indicator of heat exposure, to the laboratory and animal tests we conducted with roasted soybeans (Hsu and Satter 1995). This provided an inexpensive laboratory test for determining whether soybeans have been adequately heated. Presently the PDI test is offered commercially and is serving as the standard for evaluating heated soybeans intended for dairy diets. It has enabled implementation of quality control programs by firms that heat process soybeans for dairy cattle, and has resulted in a much improved product being marketed.

Large increases in milk production are possible when early lactation cows are fed properly heated soybeans. We conducted a lactation study to measure milk production when soybeans were heated to 295° F and steeped for 30 min (Faldet et al. 1991). Forty-six multiparous Holstein cows were fed one of three total mixed diets from 15 to 119 d postpartum with alfalfa silage as the only forage. Each diet contained 50% forage and 50% concentrate on a DM basis. Diets were formulated to be isonitrogenous by replacing corn and solvent soybean meal with raw soybeans or heat-treated soybeans. The proportion of protein supplement in the diet on a DM basis for the three groups was 10% soybean meal, 13% raw soybeans, or 13% heat-treated soybeans. The soybean meal diet was fed to all cows during week 1 and 2 postpartum for covariate adjustment of DM intake and milk production. Intake of DM was similar across diets. Feeding heat-treated soybeans supported more milk (9.9 lbs/d), 3.5% fat corrected milk (FCM) (8.8 lbs/d), and milk protein (.2 lbs/d) than soybean meal. Milk fat percentage was not altered by diet. However, milk protein percentage was depressed in cows fed heat-treated soybeans compared with soybean meal (2.85 vs. 2.99%, respectively). Figure 1 contains a plot of the unadjusted mean daily milk production for cows in this experiment. Cows fed the heat processed soybeans achieved a higher peak milk production and reached the peak 2-4 weeks later than the soybean meal group or the unheated soybean group.

A large number of lactation studies have been conducted with heat processed soybeans and there is little doubt that heated soybeans can be a very effective supplement, particularly when alfalfa silage or hay are the principal forages. Table 3 contains a summary of published and unpublished studies where roasted or extruded soybeans were compared to soybean meal or unheated soybeans in dairy diets. The average milk production response of 2.9-3.5 lb milk/day is perhaps an underestimate of po-

Table 3.
Summary of animal response to feeding of heated soybeans[1] (Socha, 1991).

| Treatment | Milk lb/d | Change in Milk fat % | Change in milk protein % | Dry matter intake lb/d |
|---|---|---|---|---|
| Roasted soybeans | 3.5 (16)[2] | +.06 (16) | -.07 (16) | -.2 (16) |
| Extruded soybeans | 2.9 (20) | -.17 (19) | -.06 (17) | +.2 (18) |

[1]Soybean meal or unheated soybeans served as the control.
[2]Number in parenthesis is the number of comparisons.

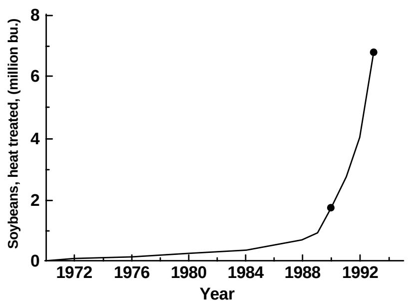


*Figure 2. Soybeans heat treated in Wisconsin from 1970 to 1993. Source: Based on telephone surveys of soybean processors in 1990 and 1993.*

tential response because underheated soybeans were used in many of the comparisons summarized in Table 3.

Based on the average milk production response shown in Table 3, properly heated soybeans are worth approximately $100 more per ton than soybean meal or unheated soybeans. Cost of roasting typically ranges between $20 and $30 per ton. Roasted soybeans are very palatable and have become a popular supplement for dairy cows. Figure 2 shows the growth in use of heated soybeans in Wisconsin. The beginning of the rapid expansion phase in the late 1980s corresponds with the availability of information coming from the US Dairy Forage Research Center concerning proper heat treatment and potential benefits from feeding properly heated soybeans. It is estimated that currently 20 million bushes of soybeans are being heat treated for dairy cattle in the US.

### *Stimulating the Rumen Fermentation; Increasing Microbial Growth and Capture of Ammonia in the Rumen*

Processing of corn grain, such as fine grinding or steam flaking, can increase both rate and extent of starch digestion in the rumen, as well as total gastrointestinal tract digestibility. We have embarked on a series of studies to quantitate the benefit for dairy cows when corn is ground to approximately 700 microns, the size typically sought for swine diets. We want to know: (1) to what extent can the digestibility of corn be increased, thus improving overall feed efficiency, and (2) to what extent can protein supplementation of the dairy cow be decreased if the corn portion of the diet is finely ground, thus enhancing microbial protein production in the rumen.

A preliminary in vitro digestibility study (Dhiman and Satter 1993b) was used to screen five differently processed corn treatments for their fermentability, using volatile fatty acid production and pH as indicators of fermentability. The five treatments in increasing order of fermentability were: dry shelled rolled corn, cracked corn, coarsely ground high moisture ear corn, flaked corn, and finely ground high moisture ear corn.

Mid-lactation cows were used in the first experiment. Dry rolled corn, high moisture ear corn, and finely ground high moisture ear corn (above) were fed in a 3 x 3 Latin square replicated nine times. Twenty-seven cows were assigned to three groups according to milk yield. Each period was three weeks, with data collected during the last two weeks of each period. Cows were fed diets containing 63.2% alfalfa silage and 35% concentrate, most of which was one of the three corn treatments. Dry shelled rolled corn and high moisture ear corn had 90.2 and 69.9% DM, respectively.

In the second experiment, thirty-seven mature cows and 34 first lactation cows were assigned before calving to one of three treatments. Cows were fed 50% forage and 50% concentrate diets (DM basis). The forage portion of the diet was 2/3 alfalfa silage and 1/3 corn silage. The concentrate portion of the diet contained either dry shelled rolled corn (Trt 1), coarsely ground high moisture ear corn (Trt 2), or finely ground high moisture ear corn (Trt 3) along with roasted soybeans and soybean meal as protein supplements. Dry shelled rolled corn and high moisture ear corn had 89 and 68% DM, respectively. The experiment started at calving and lasted until cows completed wk 30 of lactation. Particle size distribution of different corn treatments is given in Table 4.

Table 4.
Particle size distribution of corn treatments.

| Treatment | Screen mesh size, mm 4.75 | 3.36 | 1.18 | 0.6 | Pan |
|---|---|---|---|---|---|
| | % retained on the screen | | | | |
| Dry shelled rolled corn | 9.1 | 71.5 | 14.4 | 2.6 | 2.3 |
| High moisture ear corn | 56.6 | 28.4 | 6.9 | 3.1 | 5.1 |
| Ground high moisture ear corn | 1.8 | 19.7 | 23.6 | 18.1 | 36.8 |

Table 5.
Nutrient intake, milk yield, milk composition and feed efficiency in cows fed three different forms of corn.

| Measurement | Dry rolled corn | High moisture ear corn | Ground high moisture ear corn | SEM |
|---|---|---|---|---|
| Midlactation cows | | | | |
| 3.5% fat-corrected milk, lb/day | 56.1 | 57.6 | 56.1 | .66 |
| Milk fat, % | 3.41 | 3.44 | 3.36 | .04 |
| Milk protein, % | 3.04 | 3.05 | 3.04 | .01 |
| Dry matter intake, lb/day | 52.4 | 47.7 | 47.7 | .44 |
| Feed efficiency[1] | 1.08 | 1.22 | 1.18 | |
| Early through mid-lactation cows | | | | |
| 3.5% fat-corrected milk, lb/day | 70.8 | 74.8 | 75.7 | 1.3 |
| Milk fat, % | 3.75 | 3.84 | 3.75 | .1 |
| Milk protein, % | 3.14 | 3.13 | 3.13 | .04 |
| Dry matter intake, lb/day | 44.0 | 45.1 | 46.0 | 1.3 |
| Feed efficiency[1] | 1.63 | 1.68 | 1.66 | .04 |

[1]Fat-corrected milk (lb)/dry matter intake (lb)

***"Broken kernels are more completely digested than intact corn kernels."***

Results from both experiments are shown in Table 5. The most striking result of these experiments is that the high moisture ear corn either supports more milk and/or greater feed efficiency than does dry rolled corn. Modern corn hybrids have about 12% of the whole ear dry matter as cob. The cob save or combines used to harvest high moisture ear corn does not retain all of the cob, and in our case the high moisture ear corn contained 9.6% cob (dry basis). Feed efficiency in all cases was higher for the high moisture ear corn than for the dry shelled rolled corn, despite the 9.6% cob dry matter. While storage costs for ground high moisture ear corn are higher than for dry shelled corn, the drying costs and greater field losses associated with dry shelled corn, plus the loss of nutrients in the cob, strongly favor harvest of high moisture ear corn. The benefit, if any, of fine grinding of high moisture ear corn has yet to be determined. It is likely that moisture content will influence whether grinding is effective. There appears to be no benefit in terms of milk production or feed efficiency when high moisture corn does not exceed 68 - 69% DM but we have not yet determined if fine grinding will enable a reduction in supplemental protein.

## Roller Milling of Corn Silage to Increase Digestibility of Corn Kernels

Many of the large forage harvesters in Europe have a small roller mill or 'kernel cracker' as part of the forage chopper that ensures that all corn kernels are broken in the resulting silage. Broken kernels are more completely digested than intact corn kernels. Documentation of benefit from roller milling of corn silage is limited. One study is available from North America (Johnson et al. 1996), but most of the research has been done in the European setting. Two possible reasons for this are that (1) a significant amount of flint corn genetics has been used in developing the North European short season varieties, and the kernel structure may respond more to crushing than typical North American varieties, and (2) custom operations with high capacity forage choppers covering larger acreage are common in Europe. The added capital cost of a 'kernel cracker' is easier to justify in a large than in a small machine.

Concerns about energy value of corn silage in the US seem to be increasing, especially with the drier silages. This could be related to a higher percentage of corn kernels appearing in the manure when drier silages are fed. The success that corn breeders have had in selecting for rapid dry-down of corn is having the effect of shortening the harvest window in which corn silage having acceptable moisture content can be harvested. It is possible that the grain portion of corn silage is being harvested at a higher dry matter content than in the past, even with the increased emphasis on earlier harvest of corn silage (half milk line vs. black layer).

We have initiated a series of studies that will evaluate the benefit of putting corn silage through a roller mill prior to ensiling. We anticipate greater overall digestibility of corn kernels, and some small shift of starch digestion from the intestine to the rumen. This should increase microbial protein synthesis, and slightly reduce the cow's protein requirement. Our objective is to determine if the added cost of running corn silage through a roller mill prior to ensiling can be justified under North American conditions.

*"... rapid buildup of soil phosphorus is due to livestock producers not giving adequate credit for manure, resulting in surplus nutrient application as commercial fertilizer."*

*"... it is questionable whether adding phosphorus in excess of NRC recommended levels is likely to improve the impaired reproductive performance often seen in high producing cows."*

*"About 75% of the phosphorus consumed by a dairy cow is excreted in feces and urine."*

## Evaluation of National Research Council Recommendations Regarding Phosphorus Supplementation

The level of available phosphorus (Bray solution) as measured in over one-half million soil samples submitted to soil-testing laboratories in Wisconsin (Combs and Bullington 1996) has increased from an average of 34 ppm in the 1968-73 period to 50 ppm in the 1990-94 period (Note: 1 ppm available phosphorus = 2 lbs available phosphorus per acre). A level of 30-35 ppm is considered more than adequate in all but sandy soils for alfalfa, corn and soybean production. Part of this rapid buildup of soil phosphorus is due to livestock producers not giving adequate credit for manure, resulting in surplus nutrient application as commercial fertilizer.

Even with proper manure credits, and appropriate use of commercial fertilizer, some dairy farms are consistently accumulating phosphorus because imports of phosphorus to the farm in the form of protein and mineral supplements and other feeds simply exceed exports in the form of milk, cattle, and surplus grain or hay. Farms that are importing more than just protein and mineral supplement, i.e., utilizing purchased grain and/or forage, are almost certainly accumulating phosphorus, unless arrangements exist for spreading manure on neighbors' fields. Surface runoff of phosphorus from farm fields is one of the major causes of algae blooms in lakes. While much remains to be learned about the relationship between soil levels of phosphorus and potential threat to surface water quality, it is fair to say that increasing soil phosphorus levels in excess of plant need will generally increase risk of environmental damage.

The National Research Council (NRC) (1988) recommends that the typical dairy cow diet contain between .34 and .42% phosphorus, and early lactation diets (0-3 wks) should contain .49% phosphorus. These are about 10% higher than the previous NRC (1971) recommendations, reflecting concerns about phosphorus availability in the animal's intestine. Many nutritionists recommend dietary phosphorus levels that exceed the current NRC recommendations, and it is common to see dietary phosphorus levels between .5-.6% of dietary dry matter for high producing herds. One reason for justifying such high dietary phosphorus is the perception that phosphorus deficiency is contributing to reproductive failure in dairy cows. This point is probably overemphasized. It is true that acute phosphorus deficiency does reduce fertility, but it is questionable whether adding phosphorus in excess of NRC recommended levels is likely to improve the impaired reproductive performance often seen in high producing cows.

Feedstuffs grown on high phosphorus soils tend to be slightly higher in phosphorus content. Based on experience with feeds grown on the US Dairy Forage Research Center farm, dairy diets with "home grown" feeds will contain about .35% phosphorus before any phosphorus supplementation. This is not much below current NRC recommendations, and about equal to the 1971 NRC recommended level. Concerns in Europe over excessive soil phosphorus levels are causing a reduction in phosphorus supplementation, and in the Netherlands some producers add no supplemental phosphorus to dairy diets. A study in Germany (Brintrup et al. 1993) suggests that a dietary level of .33% phosphorus is adequate for lactating cows producing about 16,500 lbs/lactation.

There has been an upward "creep" in phosphorus supplementation of dairy cows in the US, and it may not be justified. Information on phosphorus requirement of the modern high producing dairy cow is needed. About 75% of the phosphorus consumed by a dairy cow is excreted in feces and urine. A lactating cow, producing 65 lbs of milk and consuming 48 lbs of diet dry matter containing .5% phosphorus, will excrete about .18 lb phosphorus daily in feces and urine, and .060 lb in milk. If the diet contains .4% phosphorus, feed and urinary excretion will be reduced to .132 lb daily, assuming no change in milk phosphorus excretion. Thus, a 20% reduction in phosphorus intake will reduce

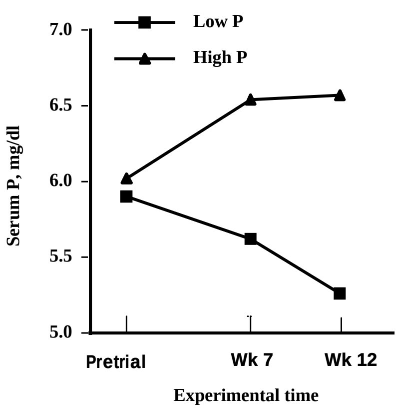


*Figure 3. Blood serum phosphorus concentrations of cows fed low and high phosphorus diets. (Each point represents an average of three samples taken from 23 cows during 3 days). SD was .62, .60, and .63 during pretrial, 7 wk, and 12 wk, respectively.*

feed and urinary excretion by 27%. The possibility for significantly reducing phosphorus excretion by our dairy herds through reduced phosphorus supplementation is extremely attractive. Quantitative information on the phosphorus requirement of high producing dairy cows is sorely needed, however.

We have initiated studies to evaluate current NRC phosphorus recommendations. In the first study, 46 mid to late lactation Holstein dairy cows were fed a pretrial diet for 10 days. At the end of the pretrial period, cows were blocked according to milk yield, and cows within blocks were assigned randomly to low phosphorus (.39% of diet DM) or high phosphorus (.65% of diet DM). Diets contained (dry basis) 45% alfalfa silage, 10% corn silage, 19% high moisture ear corn, 12% high moisture barley, 13% of a mixture of roasted soybeans and soybean meal, and the balance as mineral and vitamin mix. Sodium mono-phosphate was used to increase dietary phosphorus content.

Milk production and feed intake information is in Table 6. There were no significant effects of phosphorus intake on feed intake, milk yield or milk composition. As shown in Figure 3, concentrations of phosphorus in blood serum of cows fed the low phosphorus diet were lower (P = .06) at week 12 compared with phosphorus concentrations at week 7 of the experiment. No change in phosphorus concentration was observed between week 7 and 12 of the experiment in cows fed the high phosphorus diet. Serum phosphorus concentrations in the 5-6 mg/dl range are usually considered adequate. It is not known how much further, if any, blood serum phosphorus might decrease had the trial been extended. Longer term studies are being planned.

Supplemental phosphorus for the dairy ration represents a significant cost to dairy producers, particularly if the farm is in a surplus phosphorus state. It could be argued that if fertilizer phosphorus must be purchased for the farm cropping program, surplus phosphorus for the cow will eventually be utilized via manure application to cropland. The net cost of this would be the difference in cost between fertilizer and feed grade phosphorus sources. Assuming for the moment that .4% dietary phosphorus is adequate for the lactating cow, including the early lactation cow, reducing supplemental phosphorus from .5% to .4% of the diet would represent a savings of about 4-5¢ per cow per day, and would reduce phosphorus excretion in manure by about 27%. The meager information on phosphorus needs of the high producing dairy cow suggests that .35 to .40% dietary phosphorus might be sufficient. This needs to be verified, however. Given the build-up of soil phosphorus on many dairy farms, and the consequent increase in phosphorus content of home grown feeds, reevaluation of the cow's need for supplemental phosphorus is timely.

Table 6.
Feed intake, milk yield and milk consumption of cows fed diets containing low and high P content[1].

| | Treatment | | | |
|---|---|---|---|---|
| Measurement | Low P | High P | SEM | P |
| DM intake[2], lb/d | 48.4 | 48.6 | - - | - - |
| Milk yield, lb/d | 52.6 | 53.7 | .5 | .9 |
| 3.5% FCM, lb/d | 54.8 | 55.4 | .6 | .3 |
| Milk fat, % | 3.88 | 3.97 | .08 | .4 |
| Milk protein, % | 3.48 | 3.60 | .05 | .3 |
| Lactose, % | 4.73 | 4.71 | .04 | .07 |

[1]Covariate adjusted LS Means.
[2]Cows were fed as a group; therefore no statistical comparison was made.

## Summary

Nutrient management on the dairy farm can pay big dividends, both financially and environmentally. A better match of crop (feed) production with nutrient need of the herd, and conversely, providing manure nutrients to crops that can effectively utilize them, can reduce both cost and environmental risk. Corn and alfalfa are complimentary crops in terms of nutrient needs and in terms of nutrient supply to the dairy cow. If sufficient land is available to the dairy producer, inclusion of soybeans in the crop rotation as a potential protein supplement can greatly reduce nutrient (nitrogen and phosphorus) import to the farm. Soybeans in the crop rotation also facilitates no-till management of land in areas where soil type and growing conditions permit, further reducing cost of feed production and threat of soil erosion. While crop production has often been viewed as a competitor for a dairy producer's time, having control over the cropping program can be an important advantage when viewed in the broader context of a sustainable system for food production.

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